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OPTICAL FIBER DRAWING METHOD AND DRAWING FURNACE
[HIKARI FAIBA SENBIKI HOHO OYOBI SENBIKIRO]

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Specification

[Scope of Claims]

[Claim 1] An optical fiber drawing method comprising a step to heat and melt the bottom end of an optical fiber preform,

a step to continuously draw an optical fiber from the bottom end of the molten optical fiber preform,

a step to pass the bottom end of the optical fiber preform and the optical fiber drawn out of the bottom end of the optical fiber preform through a tapered cylinder whose inner diameter is gradually reduced toward the bottom, and

a step to supply an inert gas from the top end to the bottom end of the tapered cylinder.

[Claim 2] The optical fiber drawing method according to Claim 1 characterized in that the flow rate of the inert gas flowing inside the tapered cylinder increases toward the bottom end of the tapered cylinder.

[Claim 3] The optical fiber drawing method according to Claim 1 or 2 characterized in that the optical fiber facing the top end of the tapered cylinder is 3 mm or more in diameter.

[Claim 4] An optical fiber drawing furnace comprising a furnace core tube to receive an optical fiber preform from

the top end while an optical fiber is drawn from its bottom end, an inert gas feeder to supply an inert gas from the top end to the bottom end of this furnace core tube, a heater positioned around the furnace core tube and enclosing the bottom end of the optical fiber preform to heat and melt the preform, and a furnace body supporting the heater and furnace core tube, and

characterized in that the furnace core tube is composed of a cylinder having a given inner diameter corresponding to the outer diameter of the optical fiber perform and arranged so that its bottom end faces the molten portion of the optical fiber preform or is above the position facing the molten portion of the optical fiber perform, and

a tapered cylinder whose inner diameter is gradually reduced toward the bottom.

[Claim 5] The optical fiber drawing furnace according to Claim 4 characterized in that a cap whose inner diameter is gradually reduced toward the bottom is attached to the bottom end of the tapered cylinder, and that the rate of change of the inner diameter of the cap equals or exceeds the rate of change of the inner diameter of the tapered cylinder.

[Claim 6] The optical fiber drawing furnace according to Claim 5 characterized in that the cap is splittable in

itself, and is removable from the tapered cylinder.

[Claim 7] The optical fiber drawing furnace according to Claim 4 characterized in that the tapered cylinder is composed of a 1st tapered cylinder mainly enclosing the molten portion of the optical fiber perform, and a 2nd tapered cylinder following the 1st tapered cylinder and mainly enclosing the optical fiber, and that the rate of change of the inner diameter of the 1st tapered cylinder is larger than the rate of change of the inner diameter of the 2nd tapered cylinder.

[Claim 8] The optical fiber drawing furnace according to Claim 7 characterized in that the portion of the optical fiber facing the joint of the 1st tapered cylinder and 2nd tapered cylinder is 3 mm or more in diameter.

[Claim 9] An optical fiber drawing furnace comprising a cylindrical furnace core tube to receive an optical fiber preform from the top end while the bottom end is blocked off with a bottom plate,

a tapered cylinder whose inner diameter is gradually reduced toward the bottom, wherein its top end faces the bottom end of the optical fiber preform while an optical fiber is drawn from the bottom end, passing through the center of the bottom plate of the furnace core tube,

an inert gas feeder to supply from the top end of the

furnace core tube to the bottom end of the tapered cylinder and a gas discharge port created at the bottom end of the furnace core tube,

a heater positioned around at least the furnace core tube out of the furnace core tube and the tapered cylinder and enclosing the bottom end of the optical fiber preform to heat and melt the preform, and

a furnace body supporting the heater and furnace core tube.

[Claim 10] The optical fiber drawing furnace according to Claim 9 characterized in that a cap whose inner diameter is gradually reduced toward the bottom is attached to the bottom end of the tapered cylinder, and that the rate of change of the inner diameter of the cap equals or exceeds the rate of change of the inner diameter of the tapered cylinder.

[Claim 11] The optical fiber drawing furnace according to Claim 10 characterized in that the cap is splittable in itself, and is removable from the tapered cylinder.

[Detailed Description of the Invention]

[0001]

[Industrial Field of Application] The present invention pertains to an optical fiber drawing method designed to minimize the fluctuations in the outer diameter of an

optical fiber and an optical fiber drawing furnace capable of achieving this drawing method.

[0002]

[Prior Art] A typical optical fiber for transmission of information is fabricated by heating and melting the bottom end of an optical fiber preform a few cm in diameter having a cross section similar to that of the optical fiber, and by continuously drawing the molten portion toward the bottom. Optical fiber drawing furnaces to heat the bottom end of an optical fiber preform have been disclosed in Japanese Examined Patent Application Publication No. 1991-24421, Japanese Unexamined Patent Application Publication No. 1984-88336, etc.

[0003] For example, as shown in Figure 3, a cross sectional view showing the structure of the conventional optical fiber drawing furnace disclosed in Japanese Examined Patent Application Publication No. 1991-24421, a furnace body 102 integrating an insulator 101 houses a furnace core tube 104 to receive an optical fiber preform 103, and a ring-shaped heater 105 enclosing the center of the furnace core tube 104 to heat and melt the bottom end of the optical fiber preform 103. At the top of an inlet tube 106 projecting upward from the center of the top end of the furnace body 102, an inert gas feeder not shown in the figure is

installed to supply downward an inert gas such as helium and nitrogen to the furnace core tube 101 through the inlet tube 106. Furthermore, a cylindrical cap 107 is projecting downward from the center of the bottom end of the furnace body 102; and from a bottom opening 108 of

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this cap 107, an optical fiber 109 is drawn out.

[0004] The furnace core tube 104 is composed of a large cylinder 110 to receive the optical fiber preform 103 through the inlet tube 106, a tapered cylinder 111 whose inner diameter is gradually reduced toward the bottom joined with the large cylinder 110 at the top end and enclosing the bottom end of the optical fiber preform 103, and a small cylinder 112 joined with the bottom end of the tapered cylinder 111 at the top end and with the top end of the cap 107 at the bottom end.

[0005] Thus, the inside of the furnace body 102 is kept warm by the insulator 101, and the bottom end of the optical fiber preform 103 forwarded to the furnace core tube 104 is heated and melted by the heater 105 inside the furnace body 102, and is drawn out as the optical fiber 109 from the bottom opening 108 of the cap 107. Also, the inside of the furnace core tube 104 is kept at inert gas atmosphere by an inert gas supplied from the top of the

furnace core tube 104, preventing oxidation of the furnace core tube 104, and keeping the inside of the furnace core tube 104 clean. The inert gas flows down along the space between the inner surface of the furnace core tube 104 and the external surfaces of the optical fiber preform 103 and optical fiber 109, and is discharged from the bottom opening 108 of the cap 107.

[0006] By forming the furnace core tube 104 along the contour of the optical fiber preform 103, the flow of the inert gas along the bottom end of the molten optical fiber preform 103 will be stabilized, controlling the outer diameter fluctuations, twisting, or deterioration of strength in the optical fiber being drawn out.

[0007]

[Problems to be Solved by the Invention] The optical fiber drawing furnaces disclosed in Japanese Examined Patent Application Publication No. 1991-24421, Japanese Unexamined Patent Application Publication No. 1984-88336, etc. are designed to supply an inert gas in a laminar flow along the optical fiber preform and optical fiber, thereby controlling the fluctuations in the outer diameter, twisting due to an uneven residual stress, and deterioration of optical fiber strength due to deposition of dust particles floating inside the furnace.

[0008] Meanwhile, when connecting multiple optical fibers through an optical connector, holes and grooves need to be created on a ferrule of the optical connector to let the optical fibers through. In this case, dimensions of these holes and grooves are determined by the maximum permissible outer diameter of the optical fiber, taking into consideration the fluctuations of the outer diameter of the optical fiber. As a result, if the permissible width is large, so will the center displacement when an optical fiber having the minimum permissible outer diameter is attached to the ferrule, increasing connection losses.

[0009] The optical fiber drawing furnaces disclosed in Japanese Examined Patent Application Publication No. 1991-24421, Japanese Unexamined Patent Application Publication No. 1984-88336, etc., were able to control the fluctuations in the outer diameter of an optical fiber within ±0.5 μm with reference to the standard outer diameter; however, they are unable to control it, for example, within ±0.2 μm. This is because the flow of the inert gas along the optical fiber preform and optical fiber is still unstable even in the optical fiber drawing furnaces having the construction above, and this unstable flow of the inert gas is likely to affect the fluctuations in the outer diameter of the optical fiber.

[0010]

[Objective of the Invention] The objective of the present invention is to offer an optical fiber drawing method designed to minimize the fluctuations in the outer diameter of an optical fiber and an optical fiber drawing furnace capable of achieving this drawing method.

[0011]

[Means for Solving the Problem] A 1st mode of the present invention is an optical fiber drawing method comprising a step to heat and melt the bottom end of an optical fiber preform, a step to continuously draw an optical fiber from the bottom end of the molten optical fiber preform, a step to pass the bottom end of the optical fiber preform and the optical fiber drawn out of the bottom end of the optical fiber preform through a tapered cylinder whose inner diameter is gradually reduced toward the bottom, and a step to supply an inert gas from the top end to the bottom end of the tapered cylinder.

[0012] Here, it is desirable that the flow rate of the inert gas flowing inside the tapered cylinder increases toward the bottom end of the tapered cylinder, and that the optical fiber facing the top end of the tapered cylinder is 3 mm or more in diameter.

[0013] Meanwhile, a 2nd mode of the present invention is an

optical fiber drawing furnace comprising a furnace core tube to receive an optical fiber preform from the top end while an optical fiber is drawn from the bottom end, an inert gas feeder to supply an inert gas from the top end to the bottom end of this furnace core tube, a heater positioned around the furnace core tube and enclosing the bottom end of the optical fiber preform to heat and melt the preform, and a furnace body supporting the heater and furnace core tube, and characterized in that the furnace core tube is arranged so that its bottom end faces the molten portion of the optical fiber preform or is above the position facing the molten portion of the optical fiber perform, and is composed of a cylinder having a given inner diameter corresponding to the outer diameter of the optical fiber perform and a tapered cylinder whose inner diameter is gradually reduced toward the bottom.

[0014] Here, it is desirable that a cap whose inner diameter is gradually reduced toward the bottom is attached to the bottom end of the tapered cylinder, and that the rate of change of the inner diameter of the cap equals or exceeds the rate of change of the inner diameter of the tapered cylinder. In this case, the cap may be splittable in itself and also removable from the tapered cylinder.

[0015] It is also acceptable that the tapered cylinder is

composed of a 1st tapered cylinder mainly enclosing the molten portion of the optical fiber perform, and a 2nd tapered cylinder following the 1st tapered cylinder and mainly enclosing the optical fiber, and that the rate of change of the inner diameter of the 1st tapered cylinder is

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larger than the rate of change of the inner diameter of the 2nd tapered cylinder. In this case, it is effective that the portion of the optical fiber facing the joint of the 1st tapered cylinder and 2nd tapered cylinder is 3 mm or more in diameter.

[0016] A 3rd mode of the present invention is an optical fiber drawing furnace comprising a cylindrical furnace core tube to receive an optical fiber preform from the top end while the bottom end is blocked off with a bottom plate, a tapered cylinder whose inner diameter is gradually reduced toward the bottom, wherein its top end faces the bottom end of the optical fiber preform while an optical fiber is drawn from the bottom end, passing through the center of the bottom plate of the furnace core tube, an inert gas feeder to supply an inert gas from the top end of the furnace core tube to the bottom end of the tapered cylinder and a gas discharge port created at the bottom end of the furnace core tube, a heater positioned around at least the

furnace core tube or both the furnace core tube and the tapered cylinder and enclosing the bottom end of the optical fiber preform to heat and melt the preform, and a furnace body supporting the heater and furnace core tube.

[0017] Here, it is desirable that a cap whose inner diameter is gradually reduced toward the bottom is attached to the bottom end of the tapered cylinder, and that the rate of change of the inner diameter of the cap equals or exceeds the rate of change of the inner diameter of the tapered cylinder. In this case, the cap may be splittable in itself and also removable from the tapered cylinder.

[0018] Incidentally, the average speed U at any location inside a furnace core tube with radius r is in proportion to T/r^2. Here, T is the absolute temperature of an inert gas at the location. In practice, it is necessary to obtain the radius r and absolute temperature T at 2 to 3 locations inside the furnace core tube, and determine the inner diameter 2r of the furnace core tube so that the average speed U will increase toward the bottom. In this case, while the absolute temperature of the inert gas normally varies in the radial direction of the furnace core tube, it is usually sufficient to measure the absolute temperature at locations away from the center by r/2 for the average temperature. In this case, it is desirable not to set the

inner diameters of the tapered cylinder and the top end of the tapered cylinder larger than needed, which may obstruct the flow of the inert gas at the molten portion of the optical fiber preform located below.

[0019]

[Operation] If the flow of an inert gas is detached from the inner surface of the furnace core tube, swirls will develop outside, obstructing the stability of the inert gas flow. Detachment is more likely to occur in a flow inside the furnace core tube wherein the average flow rate decreases. Specifically, while the average flow rate of the inert gas streaming inside the cylindrical furnace core tube is constant at any locations in the longitudinal direction of the furnace core tube, the temperature of the inert gas decreases toward the bottom of the furnace core tube, causing thermal contraction, and as a result, the average flow rate of the inert gas will be slower toward the bottom of the furnace core tube, where the gas is subject to detachment. Also, if the inner surface has a projecting bend like an aperture, a discontinuous plane of the flow will occur downstream of this bend, likely to cause detachment of the gas.

[0020] In the 1st mode of the present invention, the bottom end of an optical fiber preform and an optical fiber drawn

from the bottom end of the optical fiber preform are passed through the tapered cylinder whose inner diameter is gradually reduced toward the bottom, while an inert gas is supplied from the top end to the bottom end of the tapered cylinder; as a result, the flow rate of the inert gas inside the tapered cylinder will increase as it travels toward the bottom end of the tapered cylinder, allowing the inert gas to flow along the inner surface of the furnace core tube without being detached.

[0021] If the inert gas flow is slightly obstructed at the molten portion of the optical fiber preform where it is relatively large in diameter, changes in temperature of the optical fiber preform will be negligible since the thermal capacity of the optical fiber preform at this portion is large. Actually, only the molten portion of the optical fiber preform smaller than 3 mm to 5 mm in diameter will be affected by the fluctuations in the outer diameter due to the obstructed inert gas flow.

[0022] Thus, by determining the relative positions of the top end of the tapered cylinder and the bottom end of the optical fiber preform so that the portion of the optical fiber facing the top end of the tapered cylinder will be 3 mm or more in diameter, the outer diameter of the optical fiber preform will hardly be affected by the obstructions

of the inert gas flow.

[0023] Meanwhile, in the 2nd mode of the present invention, as an optical fiber preform is supplied from the top end of the cylinder of the furnace core tube, an inert gas is simultaneously supplied by the inert gas feeder from the top end of the furnace core tube toward the bottom end of the furnace core tube. The bottom end of the optical fiber preform heated and melted by the heater will be drawn as an optical fiber from the bottom end of the tapered cylinder. The bottom end of the optical fiber preform and the optical fiber that follows are enclosed in the tapered cylinder whose inner diameter is gradually reduced toward the bottom, and the flow rate of the inert gas traveling inside the cylinder will be maximized at the bottom end.

[0024] Meanwhile, in the 3rd mode of the present invention, as an optical fiber preform is supplied from the top end of the cylinder of the furnace core tube, an inert gas is simultaneously supplied by the inert gas feeder from the top end of the furnace core tube toward the gas discharge port created at the bottom end and the bottom end of the furnace core tube. The bottom end of the optical fiber preform heated and melted by the heater will be drawn as an optical fiber from the bottom end of the tapered cylinder. The bottom end of the optical fiber preform and the optical

fiber that follows are enclosed in the tapered cylinder, whose inner diameter is gradually reduced toward the bottom, and the flow rate of the inert gas traveling inside the cylinder will be maximized at the bottom end.

[0025]

[Embodiments] An optical fiber drawing furnace, an embodiment of the present invention, will be described in detail with reference to Figure 1 showing a cross sectional view of its structure.

[0026] A furnace body 12 integrating an insulator 11 houses a furnace core tube 14 to receive an optical fiber preform 13, and a ring-shaped heater 15 enclosing the center of the furnace core tube 14 to heat and melt the bottom end of the

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optical fiber preform 13. In the center of the top end of the furnace body 12, a cylindrical inlet tube 16 is installed, projecting upward, and at the top end of the inlet tube 16, an inert gas feeder not shown in the figure is installed to supply downward an inert gas such as helium and nitrogen to the furnace core tube 11 through the inlet tube 16. Furthermore, in the center of the bottom end of the furnace body 12 are a tapered extension cylinder 17 whose inner diameter is gradually reduced toward the bottom, a flange 18 at the bottom of the extension cylinder

17 joined with a flange 19, and a tapered cap 20 whose inner diameter is gradually reduced toward the bottom, projecting downward; and from a bottom opening 21 of this cap 20, an optical fiber 22 is drawn out.

[0027] The furnace core tube 14 in this embodiment is composed of a cylinder 24 featuring a top opening 23 to receive the optical fiber preform 13 through the inlet tube 16, a 1st tapered portion 25 joined with the cylinder 24 at the top end and enclosing the bottom end of the optical fiber preform 13 as its inner diameter is gradually reduced toward the bottom, and a 2nd tapered portion 26 joined with the bottom end of the 1st tapered portion 25 at the top end and with the top end of the extension cylinder 17 at the bottom end. The displacement of the inner diameters at these joints is set to, for example, 1 mm or less so that the inner surface of the 2nd tapered portion 26 and the inner surface of the extension cylinder 17 will form a single tapered surface as a whole. Thus, it is naturally possible to integrate the extension cylinder 17 into the 2nd tapered portion 26, and to include this extension tube 17 as part of the furnace core tube 14. Also, the tilt angle of the inner surface of the 2nd tapered portion 26 with reference to the inner surface of the cylinder 24 is set lower than the tilt angle of the inner surface of the 1st

tapered portion 25 or the tilt angle of the inner surface of the cap 20. The flow rate of an inert gas streaming out of the bottom opening 21 of the cap 20 is determined so as to prevent the air outside the furnace from entering into the furnace core tube 14 from the bottom opening 21 of the cap 20.

[0028] While the inner surfaces of the 1st tapered portion 25, 2nd tapered portion 26, and extension cylinder 17 may be intricately curved according to the contour of the molten portion at the bottom end of the optical fiber preform 13, a simple conic surface for each component will be sufficient in practice.

[0029] Meanwhile, the cap 20 in this embodiment is splittable into two segments along its axial direction. When drawing the optical fiber preform 13, the cap 20 is removed in advance from the extension cylinder 17, and after drawing has begun by dropping a lump of molten glass, namely a gob, from the bottom end of the optical fiber preform 13, the flange 19 of the cap 20 is joined with the flange 18 of the extension cylinder 17. That is, the cap 20 has a split design to prevent the gob from hitting the bottom opening 21 of the cap 20 when the gob is dropped.

[0030] Thus, while the furnace body 12 is kept warm with the insulator 11, the bottom end of the optical fiber

preform 13 supplied to the furnace core tube 14 is heated and melted by the heater 15 inside the furnace body 12, and is drawn out as the optical fiber 22 from the bottom opening 21 of the cap 20. Also, the inside of the furnace core tube 14 is kept in inert gas atmosphere with the inert gas supplied from the top of the furnace core tube 14, preventing oxidation of the furnace core tube 14, and keeping the inside of the furnace core tube 14 clean. The inert gas flows down along the space between the inner surface of the furnace core tube 14 and the external surfaces of the optical fiber preform 13 and optical fiber 22, and is discharged from the bottom opening 21 of the cap 20.

[0031] To examine the effectiveness of the present invention, in the embodiment in Figure 1, the inner diameters of the cylinder 24 and the top end of the 1st tapered portion 25 were set to 90 mm, the length of the 1st tapered portion 25 (height in the vertical direction in Figure 1) to 50 mm so that the molten portion of the optical fiber preform 13 4.5 mm in diameter faces the top end of the 2nd tapered portion 26, that is, the bottom end of the 1st tapered portion 25, the length from the top end of the 2nd tapered portion 26 to the bottom end of the extension cylinder 17 to 600 mm, and the length of the cap

20 to 50 mm; helium was selected as an inert gas, and was supplied to a rate of 10 liter per minute when converted to standard conditions of 0°C and 1 atmosphere, while the optical fiber 22 125 μm in diameter was drawn from the optical fiber preform 13 72 mm in diameter at a rate of 600 m per minute. The temperature of the inert gas was measured at point A 100 mm below the bottom end of the 1st tapered portion 25, that is, the top end of the 2nd tapered portion 26, and point B 480 mm below point A and 20 mm above the top end of the cap 20, that is, the bottom end of the extension cylinder 17; and the results were 1550°C and 810°C respectively. Based on these results, the inner diameter of the bottom end of the 1st tapered portion 25, that is, the top end of the 2nd tapered portion 26, was set to 46 mm, the inner diameter of the bottom end of the extension cylinder 17 and the top end of the cap 20 to 30 mm, and the inner diameter of the bottom opening 21 of the cap 20 to 10 mm. When the optical fiber 22 was drawn again under the same conditions, the fluctuations in the outer diameter of the fiber were reduced down to 125±0.10 to 0.15 μm, an extremely small range.

[0032] Incidentally, the inner diameter of the 2nd tapered portion 26 at point A was 43.4 mm while the inner diameter of the 2nd tapered portion 26 at point B was 30.6 mm; since

the inner diameter of the 2nd tapered portion 26 on the side of point A where the flow rate of the inner gas equals the flow rate at point B will be 39.8 mm provided that the absolute temperature distribution between points A and B changes at a constant rate, demonstrating theoretically that the flow rate of the inert gas is slightly higher at point B than at point A.

[0033] Also, to examine the effectiveness of claim 8 of the present invention, the length of the cylinder 24 was extended by 40 mm to lower the joint of the 1st tapered portion 25 and 2nd tapered portion 26 by 40 mm from the construction in Figure 1; the outer diameter of the optical fiber 22 drawn in this construction was 125±0.2 to 0.3 µm, resulting in a larger fluctuation range. At this point, the optical fiber preform 13 facing the joint of the 1st tapered portion 25

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and 2nd tapered portion 26 was 2.5 mm in diameter.

[0034] Furthermore, for comparison, the conventional optical fiber drawing furnace in Figure 3 was used to draw the optical fiber 109 under nearly the same conditions as the embodiment shown in Figure 1. However, the inner diameters of the cap 107 and the small cylinder 112 were set to 20 mm, while the inner diameter of the bottom

opening 108 of the cap 107 was set to 10 mm. The results showed that the outer diameter of the drawn optical fiber 109 fluctuated in a range of 125±0.3 to 0.4 μm.

[0035] While the bottom of the furnace core tube was tapered in the embodiment in Figure 1, a tapered tube separate from the furnace core tube may be used to achieve the same effectiveness.

[0036] Figure 2 is a cross sectional view showing the structure of an optical fiber drawing furnace, another embodiment of the present invention; a furnace body 32 integrating an insulator 31 houses a cylindrical furnace core tube 34 to receive an optical fiber preform 33, and a ring-shaped heater 35 enclosing the center of the furnace core tube 34 to heat and melt the bottom end of the optical fiber preform 33. In the center of the top end of the furnace body 32, a cylindrical inlet tube 36 is installed, projecting upward, and at the top end of the inlet tube 36, an inert gas feeder not shown in the figure is installed to supply downward an inert gas such as helium and nitrogen to the furnace core tube 34 through the inlet tube 36. Furthermore, a tapered cylinder housing 38 incorporating a gas discharge port 37 is installed in a protruding manner in the center of the bottom end of the furnace body 32. Mounted to a bottom plate 39 of this tapered cylinder

housing 38 are a tapered tube 40 whose inner diameter is gradually reduced toward the bottom facing the bottom end of the optical fiber preform 33 at the top end, and a tapered connection tube 41 projecting downward from the bottom plate 39, and continuously tapered from the tapered tube 40. A flange 42 created at the bottom of the tapered connection tube 41 is joined with a flange 44 created at the top end of a tapered cap 43 whose inner diameter is gradually reduced toward the bottom, and from a bottom opening 45 of this cap 43, an optical fiber 46 is drawn out.

[0037] In this embodiment, the tilt angle of the inner surface of the tapered tube 40 is equal to the tilt angle of the inner surface of the tapered tube 41, and the displacement of the inner diameter at their joint is set to, for example, 1 mm or less so that they will form a single tapered surface as a whole. Similarly, the displacement in diameter at the joint of the tapered tube 41 and cap 43 is also set to, for example, 1 mm or less. As in the preceding embodiment, the tilt angle of the inner surface of the cap 43 is larger than the tilt angle of the inner surface of either the tapered tube 40 or tapered connection tube 41.

[0038] While the tapered tube 40 and tapered connection

tube 41 in this embodiment are separate parts, they may be integrated into a single component to pass through the bottom plate 39. Also, while the inner surface of the 1st tapered tube 40 may be intricately curved according to the contour of the molten portion at the bottom end of the optical fiber preform 33, a simple conic surface will be sufficient in practice.

[0039] Thus, while the inside of the furnace body 32 is kept warm with the insulator 31, the bottom end of the optical fiber preform 33 supplied to the furnace core tube 34 is heated and melted by the heater 35 inside the furnace body 32, and is drawn out as the optical fiber 46 from the bottom opening 45 of the cap 43. Also, the inside of the furnace core tube 34 is kept in inert gas atmosphere with the inert gas supplied from the top of the furnace core tube 34, preventing oxidation of the furnace core tube 34, and keeping the inside of the furnace core tube 34 clean. Part of the inert gas is discharged from the gas discharge port 37 of the tapered tube housing 38, while the remaining inert gas flows down along the space between the inner surfaces of the tapered tube 40 and tapered connection tube 41 and the external surfaces of the optical fiber preform 33 and optical fiber 46, and is discharged from the bottom opening 45 of the cap 43.

[0040] To examine the effectiveness of the present invention, in the embodiment in Figure 2, the dimensions and shapes of the inner surfaces of the tapered tube 40 and tapered connection tube 41 in their assembly were equalized to the dimensions and shapes of the inner surfaces of the 2nd tapered portion 26 and extension cylinder 17 in their assembly; the cap 43 was formed to be equal to the cap 20 in the previous embodiment in dimensions and shape; the inner diameter of the furnace core tube 34 was set to 90 mm; the vertical position of the tapered tube 40 was determined with reference to the furnace body 32 so that the molten portion of the optical fiber preform 33 4.5 mm in diameter faces the top end of the tapered tube 40; helium was selected as an inert gas, and was supplied to a rate of 20 liters per minute when converted to standard conditions of 0°C and 1 atmosphere, while the optical fiber 46 125 μm in diameter was drawn from the optical fiber preform 13 72 mm in diameter at a rate of 600 m per minute.

[0041] In this case, a flow rate regulating valve, not shown in the figure, incorporated in the gas discharge port 37, not shown in the figure, was controlled to discharge approximately 50% of the inert gas from the bottom opening 45 of the cap 43 through the tapered tube 40. And, when the temperature of the inert gas was measured at point C 100 mm

below the top end of the tapered tube 40, and at point D 480 mm below point C and 20 mm above the top end of the cap 43, that is, the bottom of the tapered connection tube 41, the results were 1630°C and 830°C respectively. The outer diameter of the drawn optical fiber 46 was 125±0.1 μm, reduced to an extremely small fluctuation range.

[0042] To examine the effectiveness of claim 3 of the present invention, the tapered tube 40 shown in Figure 2 was cut off 40 mm from the top, and was used for drawing; the outer diameter of the resulting optical fiber 46 fluctuated in a larger range of 125±0.2 to 0.3 μm. The molten portion of the optical fiber preform 33 facing the top end of the tapered tube 40 was 2 mm in diameter.

[0043]

[Effect of the Invention] The present invention, wherein

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the molten portion of the optical fiber preform and the inner diameter of the tapered tube enclosing the optical fiber below are tapered with their inner diameters gradually reduced toward the bottom, stabilizes the flow of the inert gas between the molten portion and the inner surface of the tapered tube, thereby reducing the fluctuations in the outer diameter of the drawn optical fiber more effectively than the conventional method.

[Brief Description of Drawings]

[Figure 1] A sectional view showing the structure of an optical fiber drawing furnace, an embodiment of the present invention.

[Figure 2] A sectional view showing the structure of an optical fiber drawing furnace, another embodiment of the present invention.

[Figure 3] A sectional view showing the structure of a conventional optical fiber drawing furnace.

[Explanation of References]

11: Insulator

12: Furnace body

13: Optical fiber preform

14: Furnace core tube

15: Heater

16: Inlet tube

17: Extension tube

18, 19: Flange

20: Cap

21: Bottom opening

22: Optical fiber

23: Top opening

24: Cylinder

25: 1st tapered portion

26: 2nd tapered portion

31: Insulator

32: Furnace body

33: Optical fiber preform

34: Furnace core tube

35: Heater

36: Inlet tube

37: Gas discharge port

38: Tapered tube housing

39: Bottom plate

40: Tapered tube

41: Tapered connecting tube

42: Flange

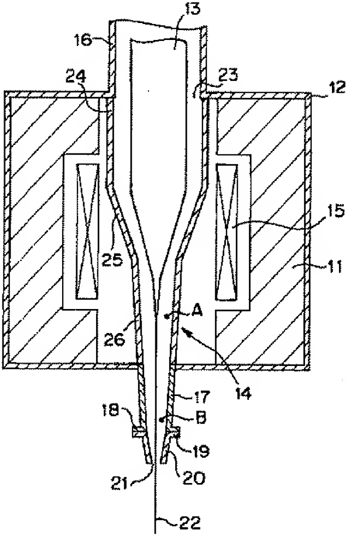
43: Cap

44: Flange

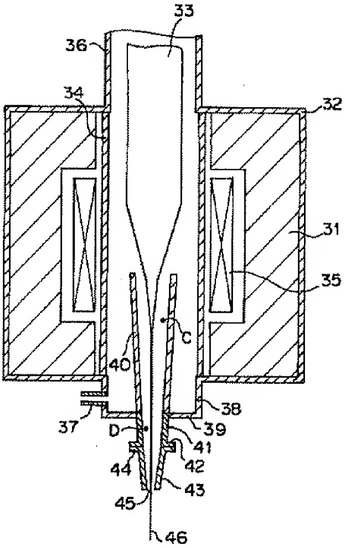
45: Bottom opening

46: Optical fiber

[Figure 1]



[Figure 2]



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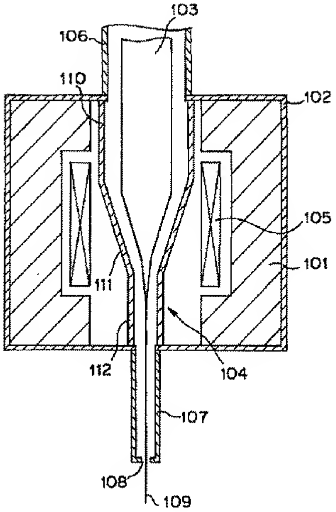
[Figure 3]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